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Comparative Study of The Method Of Oil Extraction From Bemolanga Oil Sand From Madagascar

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ABSTRACT

This study seeks to determine the best way to extract oil from Bemolanga tar sands. The study was carried out using an experimental design. Solid-liquid extraction method using Soxhlet were performed in order to optimize the extraction of asphalt content in Bemolangatar sands and reduce its environmental impact. Two solvents were used: Chloroform and TetraChloroEthylene (TCE). Regarding the choice of solvent, chloroform offers the best of 98.42% extraction yield of which 90.32% of sand and 8.10% of oil compared to97.17% of TCE yield including 89.42% of sand and 7.77% of oil. The residue obtained from the operation is free of impurity and the operation itself has minimum side effect in the environment. Environmental impact was reduced due to the fact that oil was kept in Soxhlet, and nobody was harmed. With a density ranging between 16° API and 21° API, the oil was classified as heavy oil. The obtained fraction of diesel reached more than 50% on average with minimum fraction of petrol and kerosene. The Soxhlet extraction method is identified as an ideal method for extracting oil from Bemolanga sandstone in the laboratory. The practice of this method on an industrial scale would be difficult due to the high cost of products and equipment. Nevertheless, this operation could be considered as a future pillar of Madagascar's economy with good management of resources. This operation is possible only if a way is found to optimize the extraction of bitumen from Bemolanga sandstone while keeping its main properties and protecting the environment. Indeed, the use of Soxhlet is environmentally safe but the use of solvent such as TCE and chloroform represents a considerable risk to the environment. Therefore, an implementation of new mining technology combined with a reasonable cost of operation and an environmentally safe system is the key success for a profitable Bemolanga tar sands exploitation.

Keywords: Fuel, Chloroform, distillation, solid-liquid extraction, solvent extraction, tar sand, heavy oil, Tetrachoroethylene TCE, Madagascar.

INTRODUCTION

Madagascar is rich in natural resourcesand Bemolanga tar sands are part of these resources that sparked the curiosity of oil explorers off for a century now. In 1923, Decary sought a way to exploitBemolanga deposit, is located at the bank of Mitsiotaka in the region of Morafenobe [1], and had already made studies about exploitation process [2]. Currently, Total E&P Company took the baton and made all necessary studies to determine all issues for the exploitation of Bemolanga tar sands [3].

The exploitation of this deposit can lead to major changes such as the reduction of fuel import and can help to enhance the economic development of Madagascar. The main challenge of this operation is its impact on the environment. Thus the watchword is to limit damages and increase profits.

There are a wide variety of extraction methods, and the solid-liquid extraction method is a fundamental operation that aims at extracting, separating and dissolving a liquid or one or more components (liquidor solid) mixed with a solid either by immersion or by percolation. It is the result of the structure high variability of the material to be removed and the characteristics of the elements to be extracted [4]. This solid-liquid extraction method consists in an exchange of matter between the solid phase containing the material to be extracted and the liquid phase.

Several advanatges are related to the Solvent extraction method such that the solution in the flask is enriched gradually in solute and the solid part is always into contact with freshly distilled solvent. In fact, not only is the solution in the flask enriched but also the automatic and continuous operation increases the gain of time and money [5, 6].

In this context, this study focused on the extraction of oil from Bemolanga tar sand using solvent method specifically, how to get the maximum yield of oil, free of impurities after extraction as well how to clear sand residue that can be converted after being extracted. The current study was aiming the optimization of the appropriate extraction method of heavy oil from Bemolanga tar sand and the identification of the characteristics of the obtained oil as well the sand residue.

MATERIALS AND METHODS

Description of raw materials

Bemolanga bituminous sandstone is a rock from deposits localized in the Morondava basin. The bituminous sandstone deposit Bemolanga extends between latitudes 17° 37'and 17° 52' south and on both sides of longitude 45 ° to 45 ° 16 'East [7].

Bituminous sandstone Bemolanga is a black rock, sometimes a little greyish. This rock is very crumbly and sticky due to the presence of bitumen. However, in some cases, bituminous sandstone Bemolanga is very hard. This is evidence of low bitumen content contained in the rock.

Figure 1. CrudeBemolangasandstone

Extraction methods

In this study, the wet extraction process using SOXHLET was used because of its high extraction efficiency Solid-liquid extraction method can allow the extraction of soluble components solids using solvent. The solid-liquid extraction using SOXHLET-Dean Stark is a batch process, coupling a distillation type "SOXHLET" with a cartridge containing ore imbued with the active ingredient. Oil extracted will be dissolved in a hot solvent. The batch operation brings together a quantity of crushed sandstone and solvent, then separating the inert solids from the solution, after a determined waiting time. The transfer of Material were carried out between two heterogeneous phase within a contactor i.e. the extraction is closed in a fixed bed by percolation process [8].Bituminous sandstone ore is washed in order to extract the oil and get the sand residue. From the milled ore, solute is extracted by solubilisation with solvent (Chloroform, TEC).

The distillation column produced solvent vapours that are condensed. This pure and hot solvent feeds the cartridge containing the inert solid and the solute. When the cartridge is full, the solution was (solute and solvent) automatically emptied by siphoned then returned to the boiler where the solvent is and boiled again The extraction temperature is controlled by the Dean-Stark. After extraction, the stationary phase where crushed sandstone residue remained in the cellulose cartridge and the heavy oil is completely dissolved in the solvent.

The extraction system was developed in the laboratory of geochemistry and physicochemical analysis at OMNIS.

Figure 2. Extraction system (Source : OMNIS laboratory)

Characterization method of the oil obtained

The characteristics of the extracted oil can be determined by performing the following analyses

- **The API gravity (American Petroleum Institute)**

The specific gravity of the oil is measured using a pycnometer [9].
API gravity is a scale for expressing the density of crude oil, in degrees API (° API), calculated from density,using the following formula [10]:

$$APIgravity = \frac{141,5}{gravityat\ 60°\mathrm{F}} - 131,5$$

- **Viscosity**

Viscosity is the resistance opposing molecules from a liquid to a force tending to move sliding within it. It allows appreciating the quality of liquid pumpability and defining the type of flow in the pipes.

It is determined using Fenske viscometer vessel, a container which the bottom comprises a standardized size aperture. The rate at which the fluid flows through the aperture determines the fluid viscosity. The viscosity determination is carried out by measuring the time't'of flow of the product between two line spot with a calibrated capillary tube [11].

The viscosity specifications for these heavy oil samples are intended to assure the user of a certain quality of fluidity of these products for their habitual use and very viscous fluids require more pressure for pumping. A change of viscosity of ± 25% means an oil degradation or contamination with a volatile substance [12].

- **Flammability point**

The flammability point is the lowest temperature at which a petroleum product, subjects to a small flame, present on its surface under defined conditions. The flame lights and continues to burn for a given time[13].

The analyzed sample, contained in an open vessel, is heated gradually and without interruption away from the air stream, so that its temperature rises between 5°C and 6°C per minute

- **Flash point**

The flash point of a liquid is the lowest temperature at which it is necessary to carry the vapours emitted light spontaneously in the presence of a flame under standardized conditions [13, 14].

- **Conradson carbon source**

The Conradson carbon source is the residue resulting from the heat treatment of a petroleum product under standardized conditions. Its determination is mainly carried out on the heavy product such as heavy oil.

The Conradson residue provides information on the tendency of a petroleum product to form coke in a treatment [15].

- **ASTM (American Society for Testing and Materials) distillation**

Distillation is a process for separating a binary or complex mixture, according to the boiling point of each component of the mixture.

In the result, it is expected that the various light and heavy oil fractions is distinct [16, 17].

- **Method for determining the characteristics of the sand extraction residue**

The sand extraction residue was treated before being analyzed to determine its characteristics.

Different analyses were performed, namely:

- **Particle size analysis**

Particle size analysis consists to determine the size distribution of the grains. We call rejection, the amount of material that is retained on the sieve. Fines or undersized grains are the amount of material passing through the sieve.

The particle size classification consists in fractionating particle size by a series of sieve materials in several granular classes of decreasing sizes.

The masses of the various rejection and fine are reported to the initial mass of the material. The obtained percentages are exploited in graphical form [18].

- **Chemical analysis**

Chemical analysis is designed to assay various major components in the ore such as: SiO_2, TiO_2, Fe_2O_3, CaO, MgO [19].

RESULTS

- **Extraction Result**

Each experiment was repeated at least three times with the same procedure, and the displayed values are given in Table 1.

Table 1. Extraction result with TCE and Chloroform

n°	TCE			Chloroform		
	1	2	3	1	2	3
Duration (mn)	495	705	360	240	305	250
Working temperature (°C)	100			60		
Sand content (%)	87.36	90.61	90.29	90.13	89.78	91.06
Oil content (%)	8.31	7.56	7.43	8.52	7.83	7.96
Average content of sand (%)	89.42			90,32		
Average content of oil (%)	7.77			8.10		
Yield of extraction (%)	97.17			98.42		

From the table, it is noted that chloroform presents a yield of 98.42% while for TCE it 97.17%. Both solvents are halogenated one and are convenient for the Bemolanga tar sand oil extraction. Chloroform extraction yield is higher than the one of TCE because of the high solvation of this solvent compared to TCE. However, chloroform is an apolar solvent having a boiling point of 61 ° C and a density of 1.48 g/cm^3.

- **Extracted Oil Features**

Oils are classified according to their specific densities, API (American Petroleum Institute) gravity and viscosity.

From the density test results, **H_1** oil (Oil extracted solvent Chloroform) is denser than **H_2** Oil (Oil extracted TCE solvent)(Table 2).

Table 2. Oil Characterisation obtained after extraction

Sample		H_1	H_2
Density		0,95	0,92
Gravity (°API)		16,75	21,75
Viscosity at 50°C		78,06	7,27
ASTM Distillation	IP (°C)	164	106
	FP (°C)	314	314
	Residue	18,70	6,60
	Loss	4,30	3,40
Flash Point		163	58
Flammability Point		168	66
Conradson residue		1,65	1,56

Legend: IP Initial Point, FP Final Point (IP: is the initial boiling point in which we get the first fraction, FP: is the final boiling point)

According to the value of the densities of H_1 and H_2, both are greater than 0.87, the oil extracted from Bemolanga sandstone can be classified as heavy oil.

The denser the petroleum is, the less value of API gravity is expressed [20]. The API gravity of both H_1 and H_2 oils are less than 22.3 .e. H_1 and H_2 oil are heavy oils. Therefore, low API gravity shows that H_1 is denser and more viscous than H_2.

From the above results, the following figuresare showing the distillation trend of H1 and H2 oils.

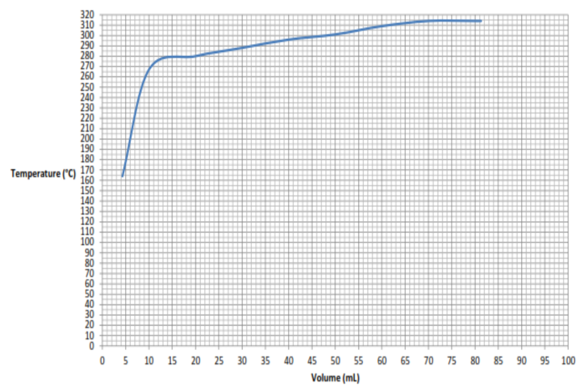

Figure 3. Distillation curve of oil H1

The petroleum fraction is evaluated from the distillation curves through different boiling temperatures at atmospheric pressure, and all the commercial fractions are resulted from [21].

Losses correlate with lighter fractions that distilled at the beginning of heating and were not condensed in the tube.Residues represent undistilled parts under the atmospheric pressure, which by distillation under vacuum give light, medium and heavy distillates. These are the origin of motor oils, bitumen (tar).

Table 3. Distillation ASTM

Sample	Loss (%)	Gasoline (%)	Kerosene (%)	Diesel (%)	Residue (%)
H_1	4.3	0.0	3.7	73.3	18.7
H_2	3.4	8.6	27.0	54.4	6.6

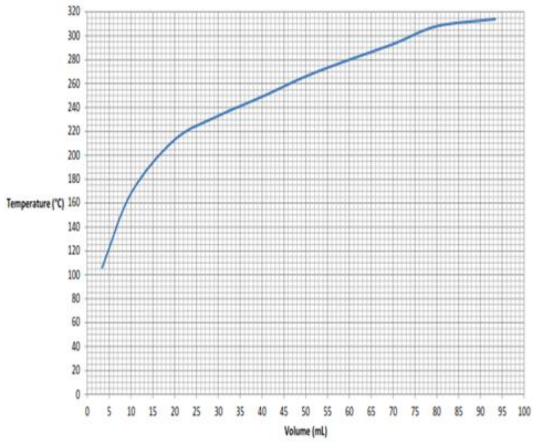

Figure 4. Distillation of H_2 oil

After the distillation of oil H_1 and H_2, the oil extracted from Bemolanga bituminous sandstone has a very low loss, equivalent to very light fractions that distilled at first, but also a very low gasoline level.

Regarding to the kerosene rate, it depends on the oil density with low density oil, a substantial fraction of kerosene can be obtained, which is the case of H_2. By cons, if the oil density is high, then the obtained kerosene fraction is low, which is the case of H_1.

H_1 residue rate is higher than H_2 residue rate and density as well viscosity are involved. Since H_1 is denser, the residue rate is significantly greater than H_2.These physicochemical properties generally have certain dependence. High density would correspond to high value of viscosity, high distillation residue content at atmospheric pressure and flammability points and high flash point, depending on the physicochemical properties of each.

- **Residue characteristics**

Particle size analysis shows the following results:

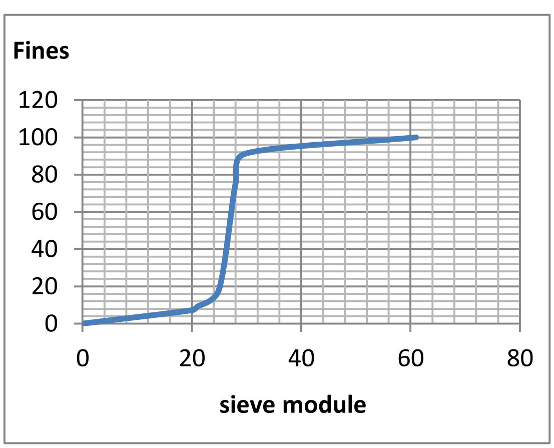

Figure 5. Particle size analysis of sand extraction residue

82.34% of our sample had a particle size between [0,100; 0.500] mm; meaning that the sand was immediately ready for use.While 9.13% of the sand used had a particle size less than 0.100 mm and 8.53% had a particle size greater than 0.500mm.

For sand having a particle size less than 0.100 mm: those between [0.080; 0.100] mm can still be used for glass; but below this size i.e. 0.080 mm it is possible that there is formation of imperfections such gas bubbles inside the glass. This sand was used in other fields (Figure 3).Thus, all of the sand sample can be used either in glassware or ceramic.

DISCUSSION

Oil refining means all treatments and transformations to produce maximum products with high commercial values from crude oil like fuel bases (gasoline, kerosene, gas oil and fuel oil), intermediate petrochemicals and plastics[22].Distillation is the first stage of refining and allows fractionation of the crude oil in order to obtain different petroleum fractions according to boiling temperature. The heavy fractions are composed of molecules of large size, very polar, rich in hetero-elements and metals. Atmospheric distillation separates the gas cuts (<35 ° C), gasoline (35-175◦C), kerosene (175- 235◦C) and diesel (235-350◦C) [23, 21].

The increasing demand of fuel is made due to rapid pace of development. As a result, great companies get into a race for unconventional oil operation. Not only is oil sand operation costly, but also their exploitation has bad side effect in the environment. Given that the crude oil contains more heavy fractions and more important ones, the oil industry has to manage its extraction in order to produce oil that would be safe in its use and would not damage the environment. In the case of Bemolanga tar sand, the challenge is to find a way to extract the oil safely and limit environmental damage.

Following this criterion, the solvent extraction using Soxhlet was an efficient method to extract oil from Bemolanga tar sand. Indeed, the results of extraction from the current report yielded up to 98% with Chloroform and the oil obtained from Bemolanga tar sand had a density of 21 ° API. In addition, the environmental impact would be limited because the extraction will be performed in a confined and insulated area.

However, during the extraction process, the choice of solvent is very important in order to optimize the results. Solvent choice is made according to several criteria:- Solubility of specific components in the solvent,- Regeneration of the solvent if it is to be reused. It should not form an azeotrope with a compound that dissolves and its latent heat should be low,- The interfacial tension and viscosity, because the solvent should properly wet the solid matrix,- Ideally it should be non-toxic, stable, non-reactive, non-flammable, environmentally safe and inexpensive,- Ready to use [23].

Generally, solvents are toxic for the environment. TCE is used as a degreaseras well has been identified as dangerous for the environment and its use is risky for the human health.

Nevertheless, chloroform is a volatile organic compound and is included in the list of 41 chemical substances characteristics of good water status [24]. Hence, it is less harmful than TCE [25]. However, the use of these two solvents is still hazardous and the solution is to find a solvent mixture that reduces the environmental impacts.

The different extraction processes of bitumen from Bemolanga tar sand fall into two distinct categories:

• The dry process or thermal

• And the wet process

The dry process technology is based on non-oxidizing pyrolysis treatment that involves distilling oil from bituminous sandstones in a blender to produce oil and gas fumes. The essential feature of the process consists of the transfer of the heat produced by the continuous circulation of pneumatically heated sand grains. The coolant is the sand.

The advantage of this method is to achieve a recovery rate of about 80%. Partial cracking leads to the formation of light fraction and reduces the viscosity from 10 ° API to 22 ° API. The system is simple, fast and product obtained is more or less already valued. In addition, environmental impact is minimized but the disadvantage of this technique is the abrasiveness of the sand coolant.

Pyrolysis method has been improved at the laboratory scale and several successful tests have been carried out using that. The results showed a 75% extraction yield with an oil content of 9% and a density of 23 ° API. The disadvantage of this method is the complexity of the equipment and its speed limit. Indeed, the process is very energy intensive. The oven must operate at least 6 hours for an extraction tower [26].

The wet process is divided into two: the first is the method of washing with hot water and the second method is the extraction with solvent.

The washing with hot water operation, applied by SPM (Society of Petroleum Madagascar) and inspired by the method applied to the oil shale in Athabasca Canada, consists on mixing the bituminous sandstone with hot water. And the separation of bitumen and sand is by flotation. This bitumen is recovered in the form of scum. Scum is then diluted in naphtha; the heterogeneous phase passes to the centrifuge to remove residual sands and other minerals. The advantages of this system are that:

• Bitumen recovery rate is 80% and the cost is acceptable compared to the thermal system. In addition, the installation of a pilot plant is feasible compared to the thermal methods which are complicated.

• The environmental impact is minimal

The disadvantage of this method is that the bitumen is very heterogeneous, thus, it is very difficult to separate the scum [27].

Extraction with solvent follows the principle of discontinuous solid-liquid extraction.and the extraction solvent is kerosene. The advantages of this method are that the recovery rate is 90% and the extraction system is very fast compared to the two previous methods. The product obtained has very good quality of bitumen. The main drawback is the high cost of extraction [28].

Compared with the results obtained in this extraction, the efficiency is improved when using chloroform. Moreover, according to this study, the residue is almost free of impurities. However, the installation of a solvent extraction unit driver is very expensive. Not only is the solvent expensive but the various devices are fragile and too expensive.

At the end, the best extraction method is the combination of two wet and dry processes. Indeed, a way out has to be found to increase the recovery rate method of washing with hot water and heat up to 95% and reduce the operating cost of the process while respecting the environment. The extraction solvent system is very useful in the laboratory but the installation of a pilot unit is not feasible because the installation is too expensive.

CONCLUSION

This study was focused on the appraisal of Bemolanga tar sand. The choice of the extraction method is very important for the obtention of a good oil yield, at least 90% without deteriorating the properties of the oil. Since the heat process changes the physicochemical properties of the heavy oil, the extraction with solvent is more suitable in terms of extraction of the oil from Bemolanga sandstone. Regarding the choice of solvent, chloroform offers a yield of 98.42%, including 98.32% of sand and 8.10% oil; compared to TCE with 97.17% only including 89.42% of sand and 7.77% of oil. However, extraction with solvent has never been applied at the industrial scale in Madagascar. Thus, the choice of extraction method of bitumen oil sand depends on the following parameters: extraction efficiency, cost and environmental protection.

After distillation, the rate of diesel for H_1 was 73.1% and 54.4% for H_2. Nevertheless, both gasoline and kerosene rate were insignificant for H_1. The rate of gasoline was 8% and the rate of kerosene was 27% for H_2. The residue could reach a rate of 12% on average. For Bemolanga tar sand, all commercial fractions were well defined, thus it is easier to increase the commercial value of its operation.

In the near future, bituminous sandstone Bemolanga will be exploited. This operation is only possible if there is a way to extract the bitumen from the sandstone in order to get better performance without destroying the environment and damage the properties of the oil. However, the operation of the sand in the area of glassmaking remains promising. In order to develop Bemolanga tar sand, further studies on the extraction method must be conducted and the installation of a pilot unit has to be refined to better appreciate this resource.

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